



Role of Boundary Organization after a Disaster: New Zealand's Natural Hazards Research Platform and the 2010–2011 Canterbury Earthquake Sequence

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Abstract: The boundary organization concept has been used to establish that collaborative arrangements and outputs across science and policy domain boundaries need to be credible, relevant, and legitimate in order to be effective. Although widely accepted in other issue-driven fields, this concept does not have equivalent currency in the natural hazard and disaster risk reduction context. This paper uses the development of the New Zealand Natural Hazards Research Platform during a recent earthquake disaster to assess the utility of the concept in this topic area. Lessons are also identified concerning the use of larger consortium organizations to increase policy and other end-user involvement in the management and coordination of research funding, and the impact of a major disaster on this research-funding initiative. Mapping the Platform's collaborative arrangements in relation to boundary tensions over time makes it possible to distinguish disaster effects from preexisting and ongoing structural effects and incentive regimes. Largely based in the research domain, this organization was well placed to resist the negative pressure of postdisaster time compression on research quality. The lack of balancing policy input at all levels made it difficult to resist the effect of this pressure on the networking required to integrate disciplinary, organizational, and higher-level science/policy domains, and thus build the legitimacy of the larger collaboration. The utility of the boundary organization concept stemmed from the emphasis on balance across domains and scales. The focus on effects, trends, and patterns serves as a counterweight to the blame attribution common after high-profile disasters. DOI: 10.1061/(ASCE)NH.1527-6996.0000202. This work is made available under the terms of the Creative Commons Attribution 4.0 International license, <http://creativecommons.org/licenses/by/4.0/>.

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Introduction

In 2009, the Natural Hazards Research Platform (the Platform) was tasked with bringing major research organizations together with policy and other stakeholders to coordinate research funding and activities in New Zealand's national interest. Within 12 months of inception, however, this newly established organization was required to coordinate the research response to New Zealand's largest natural disaster in 70 years, the 2010–2011 Canterbury earthquake sequence (Canterbury earthquakes). In this case study, the boundary organization concept is used to analyze the first five years of the Platform's development. It has two concurrent aims. Lessons are identified concerning the use of larger consortium organizations to increase policy and other end-user involvement in the management

and coordination of research funding, and the impacts of a major disaster on such research-funding initiatives. At the same time, the case study is also used to illustrate the utility of the boundary organization concept in the natural hazard and disaster risk reduction context.

The boundary organization concept is informed by a range of scholarship focused on cross-sector collaborations, including the activities of government advisory bodies, international climate change and biodiversity initiatives, and, in environmental management contexts, collaborative approaches to the management of shared resources (Jasanoff 1990; Guston 2001; Cash et al. 2003; McNie 2007; Van den Hove 2007; Berkes 2009). It is most often used to refer to collaborative arrangements used to manage the intersection or boundary, between scientific and policy domains, with the aim of facilitating the joint construction of knowledge to enrich policy and other decision making (Van den Hove 2007; Guston 2001). This concept also can be applied, to any cross-sector collaboration, and to collaborative arrangements involving multiple stakeholder domains (Cash et al. 2003; Guston 1999). All science/nonscience collaborations must deal with inevitable tensions between scientific drivers, norms, and behaviors, and those of other domains (Cash et al. 2003; Bruneel et al. 2010). The policy need for relevant, demand-driven real-time knowledge, for example, often appears in tension with the supply-driven knowledge provided in the scientific domain, and the time-consuming verification and peer-review processes required to establish scientific credibility (Cash et al. 2003; Van den Hove 2007; Sarkki et al. 2014; Clark and Majone 1985; Hackett 1997). Although boundary organizations use a range of strategies to incorporate and manage such tensions, this management is most effective when the organization produces

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outcomes that are beneficial to both—or all—of the domains involved (Guston 2001). Such collaborative activity is thus driven by the need for legitimacy, which involves fairness and balance (Cash et al. 2003; Sarkki et al. 2014; Guston 2001).

The utility of the boundary organization concept lies not only in the identification of the tensions between domain drivers that affect all such collaborations, but also in its focus on the mix of functions and processes that mitigate the inhibiting effects of these tensions. The focus is on understanding systematic effects, patterns, and trends, shifting the emphasis away from individual or organizational performance. Offering a schematic template for design, implementation, and assessment in a range of issue-driven and disciplinary fields (Van den Hove 2007), this concept has become established in areas where large, complex issues have significant economic and political consequences. These include biodiversity (Koetz et al. 2008, 2012; Sarkki et al. 2014), sustainable development (Hotes and Ogenoorh 2014; Runhaar and van Nieuwaal 2010), climate change (Lee et al. 2014; Hoppe et al. 2013; Friman and Strandberg 2014; Iyalomhe et al. 2013), and public health (Drimie and Quinlan 2011; Casale et al. 2009; Creech 2001), as well as environmental management, where the boundary organization concept first gained traction (Sternlieb et al. 2013; Pesch et al. 2012; Parker and Crona 2012; Crona and Hubacek 2010; Van den Hove 2007).

Disaster risk reduction is a complex issue of significant economic and political consequence, however there has been little application of the boundary organization concept in this context to date. This is despite widespread acknowledgment of the need for more integrative hazard and disaster research approaches (Tobin and Montz 1997; Miletti 1999; Alexander 2007; Kapucu et al. 2010). Global calls for more interdisciplinary and integrated approaches to disaster risk reduction, with closer collaboration between researchers and end users (including practitioners and communities, as well as policy and other decision makers) inform major initiatives through international science bodies, such as the International Council of Science Unions (ICSU) and the International Social Science Council (ISSC) (ICSU 2008). The drive to create a more integrated research environment is also official United Nations disaster risk reduction policy (ICSU 2003, 2005a, b, 2008, 2010; UNISDR 2005, 2011). The recent Sendai Framework for Disaster Risk Reduction, for example, commits signatory countries to the establish coordinating governance arrangements, such as national platforms, to increase the integration of stakeholders across domains, sectors, and levels, and to “foster cooperation among scientific and technological communities, other relevant stakeholders and policymakers in order to facilitate a science-policy interface for effective decision-making in disaster risk management” (UNISDR 2015, p. 13). Recent identifications of a significant research shortfall concerning the uptake of science into policy have included the need for more research into the effectiveness of research/end-user partnerships in facilitating evidence-based policies and programs (ICSU 2003, 2005a, b, 2008, 2010; Few and Barclay 2011).

This article aims to address this shortfall by assessing the utility of the boundary organization concept in the hazard and disaster context, focusing in particular on the use of such organizations after disasters. It has been well established that major disasters significantly compress the time available for policy and other decision making (Johnson and Mamula-Seddon 2014; Olshansky et al. 2012; Fordham 2007; Drabek 2007). The need for timely policy-relevant information has been in fundamental tension with the consensus building required to achieve both scientific credibility and legitimacy (Sarkki et al. 2014; Parker and Crona 2012; Hackett 1997; Fordham 2007). Thus, assessing the utility of the boundary

organization concept in this context also provides insights into the Platform’s negotiation of this tension, pointing to the value of this concept as a design tool when planning postdisaster research response. Lessons are also drawn concerning the impact of the disaster on this research-funding program, and the exacerbating effects of the postdisaster environment on initial structural constraints limiting this organization’s capacity to engage in the policy domain.

The case study is largely based on secondary data. This includes a range of Platform and other government documentation in the public domain, including the ministry of civil defense and emergency management (MCDEM) review of the emergency response (McLean et al. 2012), and the Royal Commission of Enquiry into the Canterbury earthquakes report (Cooper et al. 2012), material from the National Crisis Management Center (NCMC) log during the state of national emergency (February 22–April 30, 2011), and the 2014 Ministry of Business, Innovation, and Economics (MBIE) review of the Platform (Buwalda et al. 2014), as well as scientific and grey literature (www.greylit.org) concerning the Canterbury earthquake sequence and its impacts, as available. We also draw on observational and other data collected by the authors. All were involved in aspects of the larger response operation to this event, with some representing the Platform on the science desk at the Christchurch Response Center (SB, TW, DJ) during the state of national emergency.

Background

Boundary Organization Concept

In recent decades, complex, fragmented, and ever more globalized policy-making environments have required democratic governments to rely increasingly on nonstate scientific, financial, and other expertise for resources and cooperation (Jasanoff 1990; Gluckman 2013; Skogstad 2003). An associated emphasis on the importance of basing policy on scientific and other evidence has also fuelled calls for more integrative research approaches in order to improve the integration of science into policy and practice (Gluckman 2013; Skogstad 2003; McNie 2007). Evolving out of this wider environment, the boundary organization concept is informed by complex systems theory, ecology, and related constructivist understandings of the distinction between science and nonscience domains as a boundary between complex discursive systems (Jasanoff 1990; Guston 2001; Berkes 2009). Diverse disciplinary origins have also given rise to other closely related concepts, including science/policy interface (Van den Hoven 2007; Sarkki et al. 2014), boundary management, or systems for the translation of knowledge into action (Cash et al. 2003; Weichselgartner and Kaspersen 2012), and the umbrella term transdisciplinarity for this family of concepts (Regeer and Bunders 2009). This article uses the term boundary organization largely for the purposes of clarity. The term is also consistent with the Platform’s scope because it is often used in relation to science/policy coordination arrangements. Sometimes used interchangeably, all these concepts are concerned with the processes and tensions involved in the coproduction of socially robust knowledge by participants from research, policy, and other sectors. All share a framework based on a constructivist understanding of the boundaries between domains as dynamic zones, in an ongoing state of development through the combination of social and historical circumstance and strategic behavior described as boundary work (Guston 2001; Jasanoff 1990).

This boundary work occurs around the interfaces between domain communities, which are always in the process of being constructed by those engaged in the distinct cultures of the relevant

domains (Clark and Majone 1985; Jasanoff 1990, 2011a; Cash et al. 2003; McNie 2007). Domain activities, norms, and behaviors are driven by rules that, although simple, give rise to complex patterns of behavior. The rule-driving activities in the research domain aim for the ideal of scientific credibility; in the policy domain, the aim is to achieve political relevance. These rules inform the daily round of modifying and maintaining domain boundaries as part of professional roles and activities (McNie 2007). When science and policy fields are brought together, this process is intensified as scientists and decision makers are forced to jointly negotiate, contest, and maintain the boundary as they struggle with the fundamental tension between the rules—requiring scientific credibility and political relevance—that drive activity in each domain (Cash and Moser 2000). At this dynamic interface, or hybrid boundary zone, the strategic demarcation of scientific and other tasks involves a degree of crossover from either side (Guston 2001; Jasanoff 2011a, b; Parker and Crona 2012; Drimie and Quinlan 2011). This blurring of the boundary between these domains, though inevitable to some degree, has been productive when it comes to assembling socially robust knowledge that is of value in both domains (Jasanoff 1990; Drimie and Quinlan 2011; Iyalomhe et al. 2013). Equally, however, an associated potential for instability carries significant reciprocal risks to scientific credibility and political process, which are most apparent in debates and processes surrounding scientifically complex issues with significant and emotive political consequences, such as genetic modification, health and safety regulation, climate change, and disaster response (Jasanoff 1990, 2011a, b; Guston 2001; Hayward 2013).

The boundary organization concept begins from these premises. Since crossover between domains is inevitable, increasing, and carries significant opportunities and risks, evidence-based management of domain boundaries has the potential to increase opportunities, while also addressing the risks. Conceptualized as the agency that bridges the science/nonscience boundary, the boundary organization in effect spans and incorporates the hybrid crossover boundary zone (Guston 2001; Drimie and Quinlan 2011). Such organizations usually involve specialized roles for managing domain boundaries, which provides a forum that enables the coproduction of socially robust knowledge by participants from different domains (Guston 2001; Regeer and Bunders 2009). Accountable to principals in both domains, boundary organizations aim to manage the instability characterizing this interface by functioning for the benefit of both, or all, domains involved (Guston 2001; Cash et al. 2003). Thus, a third rule drives activities across domain boundaries, which has as its goal the ideal of legitimacy. Legitimacy involves fairness and balance, and is enhanced by transparency, inclusiveness, and consideration of the values and interests of all stakeholders (Cash et al. 2003; Cash and Moser 2000; Clark and Majone 1985; Sarkki et al. 2014; Guston 2001).

Balance across the Boundary over Time

In other topic domains, this framework has been widely used to examine the balance of tensions arising from science/policy collaborations. Demand for consultative scientific approaches involving a range of disciplines and sectors has been, and continues to be, driven from the policy domain; for example, while disciplinary research is favored in the science domain (Parker and Crona 2012; Sarkki et al. 2014; Regeer and Bunders 2009; Van den Hove 2007). Similarly, end-user preferences for clear scientific information delivered in real-time have been found to be inconsistent, respectively, with the acknowledgement of complexity and uncertainty required by scientific credibility, and with time-consuming scientific verification and peer-review processes (Van den Hove 2007; Sarkki et al. 2014).

Note that tensions are not understood to map literally or cleanly onto domains. Credibility, relevance and legitimacy are ideal goals, important to some extent to all involved in policy and research domains, where they are understood in widely different ways (Cash et al. 2003; Sarkki et al. 2014). Although balancing tensions between these domain drivers remains a goal, boundary organizations do not achieve stability, but rather enable a collaborative knowledge creation process that unfolds unpredictably over time across tensions within the hybrid boundary zone (Parker and Crona 2012; Sarkki et al. 2014). In addition to managing tensions across the boundary between larger science and policy domains, such organizations must also manage the effects of domain drivers around boundaries internal to the organization, and those which separate it from the wider environment (Parker and Crona 2012; Verweij et al. 2014).

Sarkki et al. (2014) focused on the complexity in trade-offs and synergies between differing domain processes and requirements. They found time-consuming consensus building was required both to achieve legitimacy and to ensure the credibility of scientific information through verification and peer-review processes (Sarkki et al. 2014; Parker and Crona 2012; Hackett 1997; Fordham 2007). This dictated a necessary and unavoidable trade-off with the political need for the timely or rapid provision of policy-relevant knowledge. This requirement had no synergies among either credibility or legitimacy requirements. Where other trade-offs were often context specific, or resource dependent, the trade-offs required by the relevance requirement for timeliness were found to be fundamental (Sarkki et al. 2014).

Boundary Organization Concept: Hazard and Disaster Management

Birkland (1998) established that high-profile U.S. earthquake disasters have triggered significant increases in research funding and opportunity, greater likelihood of effective science/policy collaborations, greater uptake of credible science in policy formation, and increases in disaster risk reduction policy. This is related to the time compression effect that Olshansky et al. (2012) found to be the definitive characteristic of the postdisaster environment. The destruction of services and capital greatly increases the urgency and salience of disaster response, policy, and research (Olshansky et al. 2012; Johnson and Mamula-Seddon 2014; Drabek 2007; Fordham 2007), facilitating the collaborative creation and utilization of credible, policy-relevant science identified after U.S. earthquake disasters (Birkland 1998). Equally, however, high-profile disasters have also been found to have the opposite effect. Escalating research activity at the expense of scientific quality, with large volumes of often duplicative research produced for largely opportunistic or political ends, such disasters can also drive policy informed by political need rather than—and sometimes in the face of—credible scientific evidence (Rodriguez et al. 2007; Black 2003; Birkland 2009). These risks to the credibility of science and the relevance of policy after disasters are consistent with the trade off, identified by Sarkki et al. (2014), between the timeliness requirement and the consensus building involved in scientific verification and quality-assurance processes, and required to build legitimacy.

Response and recovery structures and processes have been developed over the past 20 years to ensure that, after disasters, a range of relevant policy, practitioner, and other networks are activated and brought to bear on the accelerated decision making required in the postdisaster environment (Drabek 2007; Johnson and Mamula-Seddon 2014). To this extent, they can be seen as boundary-management arrangements. In New Zealand, the

modular coordinating incident management system (CIMS) was introduced in 2004 as a nested framework, feeding from local through regional or group level to the national level (MCDEM 2009). This incident management system brings a range of relevant agencies together with providers of lifelines, welfare, and emergency services to provide a decision-making structure that can be used after hazard events. Requiring that those involved in such responses meet regularly to train, plan, and conduct exercises together, this system is designed to build local and national networks, and thus lay the groundwork for future response operations (Helm 2009).

This modular incident management system was introduced as part of a decentralizing, deliberative, and integrated national approach to both managing and researching natural hazard and disaster risk (Johnson and Mamula-Seddon 2014; Helm 1996, 2009; Smith 2009). Devolving responsibility for risk to local and regional levels, with the goal of increasing both horizontal and vertical networking at (and between) those levels, this approach was and still is explicitly aimed at increasing the overall resilience of the larger complex system that includes both natural hazards and society (Helm 1996, 2009; Smith 2009).

Natural Hazards Research Platform

The Natural Hazards Research Platform was also established in 2009 to foster networking—across disciplines, organizations, and sectors—to further the larger policy goal of “a New Zealand society that is more resilient to natural hazards” (NHRP 2009b, p. 5). The immediate catalyst for this initiative, however, was not recognition of the need for an equivalent organization to address the accelerated research decision making and production required after disasters, but rather a 2007 international ranking of the New Zealand research environment as the most competitive of all Organization for Economic Cooperation and Development signatory nations (Smith 2009). National Research Platforms in several areas of national significance were planned to counter the negative effects of the competitive climate by ensuring longer-term research funding, and by fostering a less competitive, more stable, more collaborative research culture in these areas (NHRP 2009a). Established as the first pilot national research platform, the Platform was to examine this concept in the hazard and disaster area (NHRP 2009a). This consortium was required to bring senior research and policy representatives together to integrate medium- to long-term research and funding and was also tasked with developing new, more collaborative networks between the organizations, disciplines, and agencies already engaged in this arena. Decision-making goals included the allocation of government funding in order to further the delivery of specific intermediate outcomes in support of government-endorsed strategies, as well as the development of research capability and networks that produced outputs of the highest scientific quality (NHRP 2009a, b).

For Guston, three criteria are definitive of boundary organizations: providing opportunities and incentives for the creation of boundary objects, such organizations involve participation from both scientific and policy domains, and are situated at the intersection of these domains, with “distinct lines of accountability to each” (Guston 2001, pp. 400–401). The Platform meets all these criteria to some extent. Using it to assess the utility of this concept in the hazard and disaster context also builds a more nuanced picture of the extent to which participation and accountability mechanisms situate this boundary organization in relation to both research and policy goals.

At inception, the Platform included the six major research organizations responsible for the majority of nationally funded

hazard and disaster research in 2009 (Fig. 2). The National Institute of Weather and Atmospheric Research (NIWA) and the Platform host organization, GNS Science, are crown-owned companies required to conduct scientific research for New Zealand’s benefit [Sections 4 and 5.1(a), CRI Act 1992]. What was new about the Platform was that it brought these crown research institutes together not only with Opus, a private research consultancy, but also with three of New Zealand’s eight universities, the Universities of Canterbury and Auckland, and Massey University. As arbiters of academic quality, tertiary institutions are also responsible for building national research capacity through teaching and research programs.

In addition to integrating research activities across these organizations, the Platform was also required to integrate relevant disciplines into five broad thematic areas. Risk evaluation models are a type of boundary object; the risk and resilience themes were to cut across and thus integrate the three themes with a much longer traditional association with hazard and disaster management: geological hazards models, weather and flood prediction, and resilient buildings and infrastructure. The Platform tested a new mechanism for strategic integration across the science/policy boundary, the strategic advisory group, which brought representatives of relevant agencies and other end users together at least twice a year to provide support and guidance concerning strategic research funding decisions made by the Platform (Fig. 2). Operational integration with agency end users was to occur on a consultation basis, at both management group and theme level.

Structure—Demarcation of Tasks and Responsibilities

The Platform governance structure was hierarchical, with host, anchor, and funding organizations represented at the top tier through the Anchor CEO group (Fig. 1).

Below this level, the Platform management group comprised senior representatives of Platform research organizations. Ultimate decision-making responsibility for the demarcation of broader research funding priorities rested with this group, under the oversight of the Anchor CEO Group (NHRP 2009a, b). Chaired by the Platform manager (required to be an eminent scientist employed by the host CRI), this group did not include policy or other stakeholder representatives, although it did receive advice (at least twice a year) from the strategic advisory group (Fig. 1). Research theme leaders reported to, and were advised by the management group. Individual contestable research programs were externally peer reviewed, and sub-contracts devolved responsibility for the detail of such programs to relevant lead research organization (s) (NHRP 2009b).

The Platform’s decision-making structure thus indicated that, at the outset, research organizations and research funders had more power to influence decision making than policy and end users, concerning both broader strategic research funding priorities, and individual research programs. Within this more powerful research bloc, the host Crown Research Institute had more influence than other member organizations.

Function—Substantive Scope

This structural effect contrasts, however, with the emphasis in the six principles provided in the Platform interim strategy to guide decision making (NHRP 2009a). When mapped onto the spectrum of boundary tensions, these decision-making goals cluster at the policy end of this continuum (Fig. 2).

Positioned at the policy end of this spectrum, four of the six specified Platform principles reflect an active strategic approach toward driving more evidence-based policy. These principles indicated that end users should be engaged not only in deciding broad

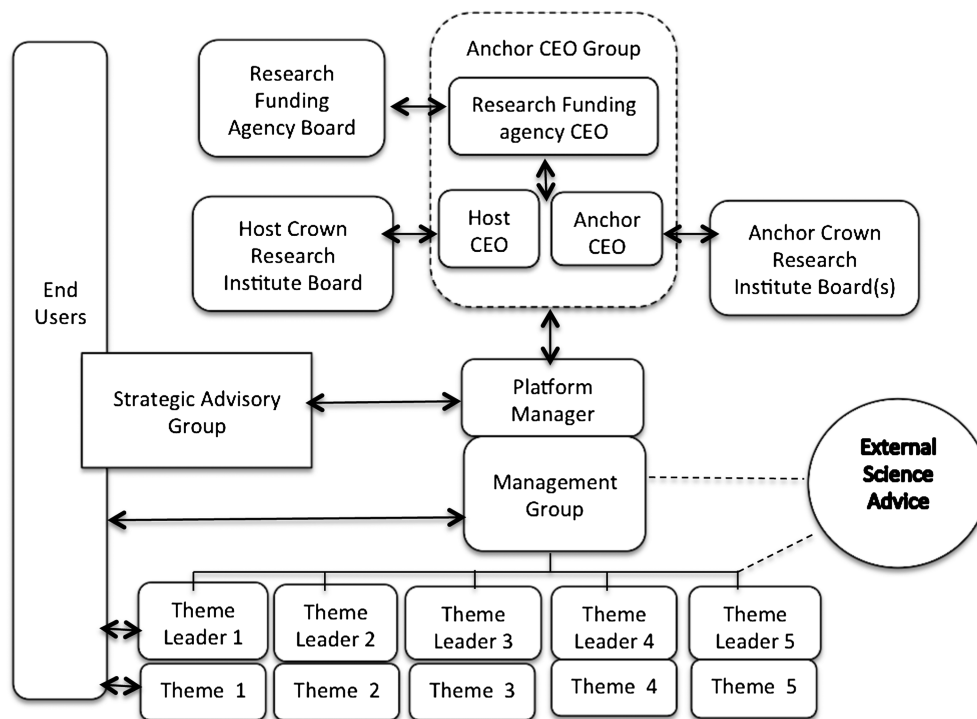


Fig. 1. The governance structure of the New Zealand NHRP (adapted from NHRP)

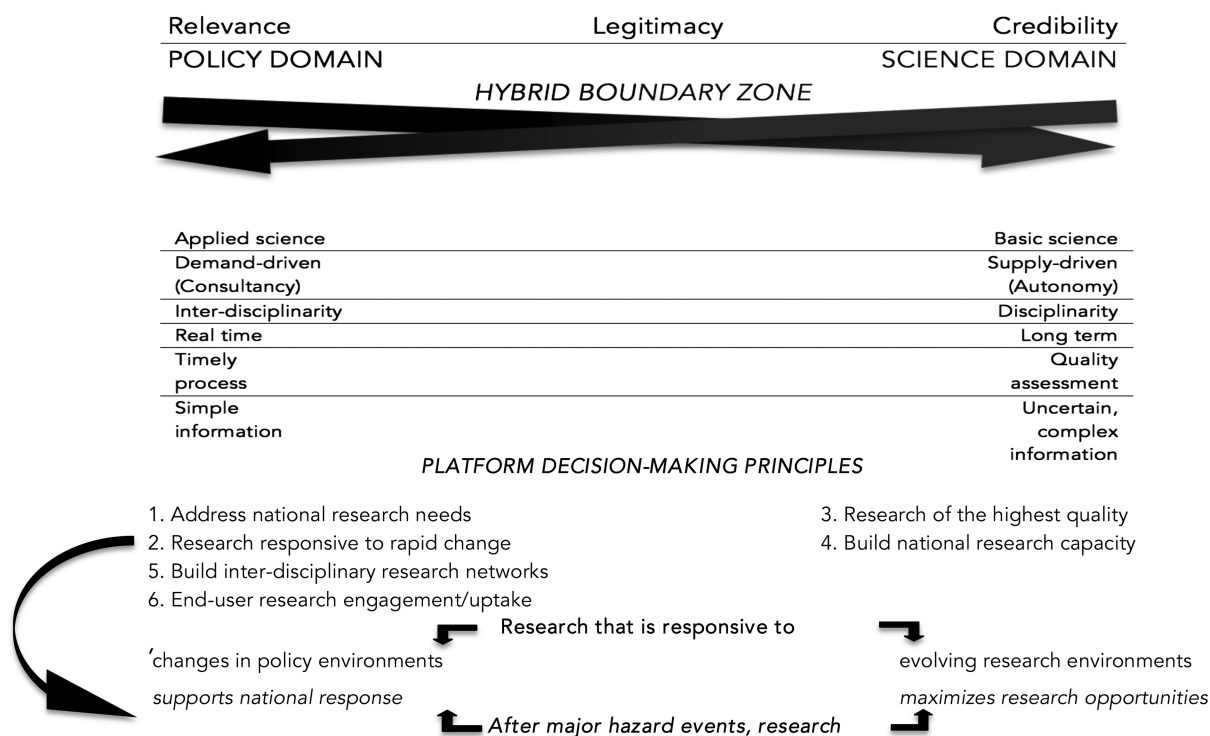


Fig. 2. NHRP research principles aligned with the spectrum of tensions within the boundary zone between policy and science domains (adapted from Sarkki et al. 2014; Parker and Crona 2012)

research direction, but also wherever possible, in all stages of the research process (including decision making). This is consistent with the high-level recognition of the need to strategically manage collaboration across the science/policy boundary in the national

interest that led to the Platform's establishment. Even those principles requiring the Platform to work with end users to provide policy-relevant outcomes, however, are solely concerned with the production of research. Founding documents do not include

balancing provisions for Platform involvement in policy formation (at any level).

Contractual arrangements also reflect the predominance of research domain drivers. The Platform partnership agreement is signed by a research funding agency and research organizations (all situated in the research domain), and focused on managing research outputs and tensions between research organizations (NHRP 2009b). Similarly, the multiparty foundation contract specifies contractual obligations between Platform host and anchor organizations and the funding agency, while funding for research programs was subcontracted to member organizations by the Platform (NHRP 2009a). At each contractual level, all partners were based in the research domain, and contractual obligations concerned research quality and productivity (measured in relation to peer-reviewed publications).

Decision-making principles required a focus on the coproduction of policy-relevant research with representatives from the policy domain. At inception, however, the structure and function of this new research-funding organization dictated that the Platform remained almost entirely driven by research domain drivers, leaving it awkwardly situated across the tension spectrum that characterized the science/policy boundary. This was largely a reflection of historical context. In hindsight, however, the establishment of a Natural Hazards Platform incorporating agencies and research organizations to a similar degree might have produced a structure more conducive to active policy engagement in research funding decision making, as well as research involvement in policy decision making.

Disaster Response

This larger tension between domain drivers is reproduced at more detailed levels. The principle requiring the Platform to provide research advice and support to the government after major hazard events, for example, as a short-term rapid research response principle is situated at the applied end of the tension spectrum. When considered in detail, however, it also maps across the larger spectrum. Specifying that research should be responsive to rapid changes in both policy and research environments, it requires research support for government response efforts and the Platform's maximization of the research opportunities created by hazard events (Fig. 2).

The policy/science tensions surrounding the responsive research principle can be related to the differing roles of member organizations. As Crown Research Institutes, NIWA and GNS Science had existing responsibility for providing science advice to policy makers, and after major hazard events (Berryman 2012). As arbiters of research quality, universities are necessarily engaged with changes from evolving research environments, and are also responsible for maximizing research opportunities wherever possible. Prior to the Platform, there had been few formal mechanisms to coordinate a science/research, information/service provision into national, regional, or local civil defense and emergency management frameworks. Arrangements tended to be hazard and/or region specific (as in regional volcano advisory groups, and regional and national tsunami advisory groups).

The potential advantage of the Platform arrangement was that for the first time it created an official avenue for widespread research collaboration in support of emergency response and recovery operations, which included academic and private organizations as well as Crown Research Institutes. Linked into organizational, disciplinary, and international research networks, as well as connected into agencies, this new structure provided a mechanism to bring the resources of these networks to bear on the accelerated decision making and research activity required after

disasters. At the same time, it also allowed for mobilizing widespread, coordinated hazard and disaster research in order to address the research opportunities created by disasters (Beaven et al. 2015).

These potential advantages were put to the test almost immediately, when coordination of research activity during and after the 2010–2011 Canterbury earthquake sequence fell within the remit of the Platform.

Canterbury Earthquake Sequence

On September 4, 2010, the Mw 7.1 Darfield earthquake occurred, 10-km deep and ~35 km west of Christchurch, New Zealand's second largest city [population 390,300 as of June 2010 (<http://www.stats.govt.nz/>)]. This was the first in a 16-month sequence of earthquakes that trended eastward across Christchurch (Bradley et al. 2014).

The M_w 6.2 Christchurch Earthquake, the second and most damaging of these events, caused 185 deaths and more than 6,500 injuries (Johnston et al. 2014). The scale of this disaster and the magnitude of the required response and recovery operations, led to the declaration of New Zealand's first state of national emergency. This lasted until the activation of the Canterbury Earthquake Recovery Authority (CERA) on May 1, 2011. A purpose-built central government agency of limited duration, CERA was tasked with managing the overall recovery strategy and given a range of powers designed to reduce obstacles to recovery decision making (Johnson and Mamula-Seadon 2014).

The total cost of recovery and reconstruction has been estimated at as much as NZ\$40 billion, which is equivalent to approximately 19% of New Zealand's GDP (Stevenson et al. 2014).

The Platform was mandated to coordinate the science response to the Canterbury earthquake sequence. Required to support the government response effort and to maximize research opportunities, the Platform funded and coordinated a range of research activities in support of both response and recovery agencies (for an outline of the effects of this sequence and the Platform's science coordination role, see Beaven et al. 2015).

Discussion

Despite initial constraints, it is clear that this large consortium of research organizations and agencies was able to bring a new level of research networking capacity to bear on collaborative decision making with response and recovery operations (Beaven et al. 2015). Review documents confirm the Platform played a major role in the production of a coordinated range of high-quality, earthquake-related scientific outputs (McLean et al. 2012; Buwalda et al. 2014), many of which fed directly into policy and practice decisions (Berryman 2012). The inclusion of a new science liaison function in the Christchurch Response Center, and more recent provision in the new draft of the Civil Defense and Emergency Management plan for the Platform to coordinate emergency research support in future events (MCDEM 2014) also testify to the unprecedented levels of collaboration with response agencies achieved during and after these earthquakes (Berryman 2012). As a pilot, the Platform demonstrated that it is possible to use a boundary organization to bring a large section of the hazard and disaster research community into collaboration with the response operation (Buwalda et al. 2014). To this extent, it functioned as the research equivalent of the response and recovery structures, such as the Coordinated Incident Management System and CERA, which also bring the resources of multiple agencies into postdisaster decision

making and activities. In addition, this research effort established that such boundary organizations have the potential to coordinate research activity after major disaster events in such a way as to convert the urgency created by the hazard event to increase the uptake of research opportunities, including the opportunity to engage end users, and the provision of scientific evidence as the basis of decision making (Berryman 2012; Beaven et al. 2015; Buwalda et al. 2014).

Findings from other disaster events indicate that demand for rapid research provision can require trade-offs related to research quality assessment and verification processes, meaning that rapid research provision of this kind can occur at the expense of scientific credibility (Sarkki et al. 2014; Parker and Crona 2012; Hackett 1997; Birkland 2009; Black 2003). There is evidence, however, that rather than compromising quality and productivity, the pressure to respond to this earthquake disaster had a positive effect in relation to both Canterbury earthquake-related research, and the larger Platform research effort (Buwalda et al. 2014; McLean et al. 2012). All contracted annual quality and productivity standards were met or exceeded over the first four years of Platform operation, and the introduction of this boundary organization resulted in a significant improvement in overall national hazard and disaster research quality and productivity during this period (Buwalda et al. 2014). Like the existence of contractual research quality standards, this performance is consistent with the strong research grounding and focus of the Platform, its component research organizations, and the funding agency.

There is no doubt that the pressure to respond to the Canterbury earthquake sequence resulted in increased operational integration between disciplines and organizations, as well as with end users. This represented a significant rebalancing of Platform focus and activity at the operational level because it produced research of good quality that was also relevant to the needs of operational agencies. However, there are also some indications that the Platform's strong grounding in the research sector left it exposed to the effects of the trade-off, identified by Sarkki et al. (2014), between the demand for rapid research provision and the consensus building required to establish the legitimacy of cross-boundary collaborations, and that this may have been at the expense of integration at other levels.

Legitimacy and Organizational Integration

In the postdisaster environment, the Platform provided for the first time a national integrating mechanism capable of drawing on a range of academic, Crown Research Institute, and private research organizations, and of reaching back into organizational, disciplinary, and international research networks in order to bring the considerable resources of these networks to bear on the accelerated decision making and research activity required after disasters. However, while the effectiveness of this mechanism can be discerned in the quality and range of earthquake-related research activity, the number of organizations involved, and the uptake of research findings in policy and decision making, this integration effort remained largely behind the scenes.

This was due in part to the lack of provision in the Platform's founding documents for the specific distribution of responsibilities and demarcation of tasks between organizations after hazard events. There were also no strategies, protocols, or processes for managing the implicit tensions between organizations, and between their traditional spheres of responsibility. In the absence of formalized guidance, those involved in both the Platform and the response operation shared the assumption that the Platform director, who was also the chair of the Platform

management group, would lead and be the face of the effort that was coordinated through decision making by the management group, theme leaders, and others involved in this collaborative research effort. The Platform director's authority as an eminent scientist, and considerable experience providing earthquake advice on behalf of GNS before the advent of the Platform further qualified him for this role.

As the earthquake sequence unfolded, however, this experience, and the fact that the director was based in GNS science while representing the Platform during this period, appeared to aggravate the effect of the structural crossover between the new Platform role and the traditional, and more familiar advisory and support responsibilities of its host organization. After the Christchurch earthquake, the Platform director and other GNS staff relocated to the Christchurch Response Center to facilitate a clear conduit for seismology and land-damage information, as well as engage with the other research programs run out of this center. This made it more difficult for some of the programs not based in the center to engage with the Platform operation. At the same time, assumptions as to the demarcation of tasks and responsibilities between the Crown Research Institute and the larger consortium defaulted increasingly to GNS Science (Buwalda et al. 2014). Civil defense and emergency management logs at all levels referred to GNS when referencing science and research coordination, while those representing the Platform were consistently understood by agencies to be working for GNS Science. Similarly, others working in the Christchurch Response Center often described the Science Liaison desk as the "GNS desk." Later, this continued in an ongoing lack of reference to the Platform in most high-level official review documents, including the Ministry of Civil Defense and Emergency Management review and the Royal Commission of Enquiry, which, like the National Crisis Management Center log, referred only to GNS Science in relation to science and research coordination in the Christchurch Response Center (e.g., Cooper et al. 2012; McLean et al. 2012; OAG 2012).

Almost completely invisible in this official sphere, the larger Platform coordination effort appeared to have been eclipsed by the traditional role of its host organization. This was not the case in fact as the Platform retained official responsibility for the science coordination effort during this period. Decisions made by the management group resulted in the extensive involvement of member organizations and their networks in both Platform decision making, and the range of research programs that made up this effort. The lack of visibility, however, created the perception of a major imbalance between platform organizations. This left the Platform exposed to the perception that its funding and operational research activities were being conducted during this time by, and for the benefit of, a single member organization. It has been well established that the perception of the interests of one group being privileged at the expense of others risks bringing the legitimacy of the relevant collaborative activity into question, thus putting the larger collaborative enterprise at risk (Cash et al. 2003; McNie 2007; Parker and Crona 2012). Hence, the invisibility of the Platform during and after the Canterbury earthquake sequence inhibited its ability to integrate both member organizations, and recruit new partners, working against gains in organizational integration created by the urgency of this event.

The reversion of the Platform brand to that of member organizations has been identified as an issue that continues to inhibit this boundary organization's ability to build relationships with end users, as well as stakeholders (Buwalda et al. 2014), suggesting that this postdisaster effect continued to have an impact on the overall development of Platform management and strategy.

Legitimacy and Thematic (Disciplinary) Integration

The Platform's difficulty integrating partner organizations has been related to the consortium's limited progress in the area of disciplinary or thematic integration (Buwalda et al. 2014). At inception, the Platform research focus was structured into broad themes, in an attempt to bring organizations and disciplines together within themes, so fostering integration (Fig. 2). Loosely corresponding with larger disciplinary formations, the three larger more traditional themes were also broadly aligned with the interests of member organizations: geological perils was led by GNS, weather-related perils by NIWA, and the resilient buildings and infrastructure program largely driven through engineering programs at the Universities of Canterbury and Auckland (Buwalda et al. 2014).

The subcontractual funding of major thematic research programs to individual organizations reinforced the tendency of these first three themes to continue to evolve in parallel. Risk and societal resilience were subsequently added as crosscutting themes. In the absence of formal integrating mechanisms, and due to the subcontractual approach to awarding research funding, there were few opportunities for these themes (led by GNS) to function in a cross-cutting, integrating capacity. Evidence from environmental management and climate change research organizations indicates that formalized disciplinary integration mechanisms, including universal incentive and accountability regimes are more likely to create stable inter-disciplinary practices and cultures than informal mechanisms and 'charismatic' leadership (Lengwiler 2006).

The lack of formal integration mechanisms in the Platform meant that the research response loosely coordinated by the Platform after the Darfield earthquake rapidly evolved into the parallel geological, socioeconomic, and engineering research programs evident in the subsequent diagrammatic representation of the Christchurch Response Center's science function (McLean et al. 2012). While the development of these programs was organic, this thematic structure was consistent with that of the Platform. Although the majority of this research activity was funded through the Platform, who also provided science advice to agencies within the Christchurch Response Center, the coordination of these programs fell into three distinct and largely discrete research streams, coordinated by and through relevant member organizations. Only the geological and socioeconomic research programs were operationally coordinated out of the Christchurch Response Center by Platform theme leaders (both were also GNS scientists). Structural engineering assessment and data collecting programs were run as a parallel, but entirely stand-alone operation (McLean et al. 2012) coordinated by engineers from the Universities of Auckland and Canterbury in collaboration with the department of building and housing. Scientists from the regional and city council response operations (respectively) were jointly responsible for coordinating the wider geotechnical research program in collaboration with member organizations and other private research providers. This included investigations of rock-fall and slope stability, as well as liquefaction and related ground and foundation damage. Although employed by responding agencies rather than Platform member organizations, these scientists were also based at the science desk in the Christchurch Response Center.

The response operation was similarly structured into discrete agencies with distinct responsibilities for building and housing, infrastructure and lifelines, land planning, and social services. Mapping onto this response operation, the streamed research effort reflected not only the Platform thematic structure, but also the salience of demand-driven research and information created by the postdisaster environment.

Individual time constraints have been found to be a significant barrier to interdisciplinarity, as well as other types of integration, during business-as-usual conditions (Parker and Crona 2012; Sarkki et al. 2014). In the absence of formal integration mechanisms, under increased time pressure, and in response to urgent agency demand, the Platform consortium structure appeared to have fallen back on the resources of member organizations, and so decoupled into discrete and largely monothematic organizational operations. The impact of the Canterbury earthquake sequence on the Platform at this early and formative stage in its development is likely to have been a significant factor in the consortium's continuing struggle to increase thematic integration.

Legitimacy and Higher-Level Integration

Although meeting or exceeding research quality and productivity standards during its first four years of operation, the Platform was found to have continued to manifest a largely operational focus on providing research in response to agency demand (Buwalda et al. 2014). Working to some extent at the expense of higher-level strategic integration, this focus was also hazard-centric, and to this extent may have inhibited the development of a research strategy more explicitly focused on the resilient outcomes required by the Crown policy strategy (Buwalda et al. 2014). From a boundary management perspective, these findings are consistent with the structural imbalance that positioned this organization largely in the research domain, and the disaster effect that aggravated rather than ameliorated the effects of that imbalance.

At its inception, the Platform was charged with strategically managing the national hazard and disaster research investment in conjunction with the agencies and other end users, but lacked effective structural and functional mechanisms to achieve this duty. Founding documents also limited the scope of Platform activities to the research sphere, making no reference to or provision for Platform involvement in the coproduction of policy strategy. Almost immediately, the impact of the Canterbury earthquake sequence catalyzed an overwhelming operational focus, driving the collaborative operational decision making with response and recovery agencies evidenced in scientific outputs that fed into earthquake-related policy and other decision making, and first-time inclusions of science as a function in the coordinated incident management system structure, and of the Platform in more recent Civil Defense and Emergency Management response plans (CDEM draft plan 2014).

The main incentive and accountability mechanism driving Platform activity during this four-year period allowed it to maintain high research quality despite this operational focus, but there lacked a balancing emphasis on the coproduction of research and policy strategies that focused on resilient outcomes. Resilient research outcomes are determined by the extent to which research activities and outputs are relevant to the goal of Crown policy strategy: "a New Zealand society that is more resilient to natural hazards." (NHRP 2009b, p. 5). By contrast, a hazards focus aligns with distinct research disciplines: geological hazards (volcanoes, earthquakes, landslides, rockfalls), climatological and coastal hazards (cyclones, tornadoes, flooding, excessive snowfalls, tsunami), and the hazard-centric engineering branches (earthquake engineering, fire engineering, hydrological engineering, geotechnical engineering). In effect, Platform contractual requirements prioritized research quality over thematic integration. Research productivity and quality standards were measured with reference to disciplinary peer review quality assessment processes, and the quantity and impact status of peer-reviewed publications (Buwalda et al. 2014). Rather than simply reflecting an oversight on the part of Platform

leadership or management, the tenacity of this boundary organization's thematic structure was strongly reinforced by contractual obligations, which thereby worked against the development of a research strategy focused on resilient outcomes.

There is evidence that the postdisaster environment may have cemented these constraints, further inhibiting this boundary organization's ability to develop higher-level strategic alliances in the policy sector. The increased relevance of hazard and disaster research created by the Canterbury earthquake sequence led to a number of calls for research proposals addressing the earthquakes in 2012 funding rounds. Those from agencies with existing links to the Platform, such as the department of building and housing, were made in consultation with the Platform. Other earthquake funding rounds from agencies with no prior record of funding research in this area, such as the Health Research Council (HRC), were made independently. The Platform's interim strategy document tasked the consortium with contributing to the coordination of hazard and disaster research funding across government agencies (NHRP 2009b). Thus, the 2012 funding round represented an opportunity for the Platform to coordinate research funding across government agencies, as per its mandate, and thereby engage with new potential end-user agencies at the strategic level. Coordination across agencies on this occasion could also have increased integration at both disciplinary organizational levels by bringing a new range of researchers and agencies together, thus consolidating larger collaborative research programs.

The Platform lacked mechanisms for this kind of high-level coordination activity with other funding agencies, and for encouraging agencies to consult with the Platform when funding disaster-related research policy engagement. Together with the invisibility of the Platform brand, the narrowing of Platform focus onto operational engagement with end users and the involvement of funding agencies not previously involved in the hazard and disaster management arena, this appeared to contribute to a breakdown of communication at this higher level between some new potential end-user agencies and the Platform regarding 2012 Canterbury earthquake sequence research-funding initiatives. Several non-Platform funding rounds calling for earthquake-related research proposals occurred and were awarded without consultation with the Platform. In the social science arena, this led to a number of new, more or less parallel funded projects focused on community resilience, alongside an existing longer-term Platform community resilience research program. In addition to reflecting a breakdown of communication between funding bodies, this outcome also pointed to a lack of provision for translating the considerable body of existing research, as well as Platform-funded programs already underway at the time, into terms which would make it accessible to this wider range of research funding agencies.

Conclusions

The boundary organization concept provides a schematic template that makes it possible to build a nuanced model of the way domain driver interactions combined with the effects of the 2010–2011 earthquake disaster to shape the development of the Platform during its first four years. This closing section draws from this model to illustrate three broad aspects of the utility of this concept that arise from its grounding in complexity theory, before ending with some concluding comments about anticipating the influence of disasters on research/policy collaborations when designing boundary organizations in this area.

The first aspect of this concept that makes it useful in the hazard and disaster context is its continuing emphasis on the importance

of balance. Driving collaboration between domains, the goal of legitimacy is enhanced by balance between research and policy domains; more balanced participation, functional, and structural elements contribute to more balance in the influence of the rules that govern activity within each domain. Perfect balance is of course unachievable—legitimacy is an ideal, like credibility and relevance. However, aiming for this balance helps clarify the imbalances that can inhibit cross-boundary collaborations. When Platform scope (function) and the demarcation of tasks and responsibilities (structure) were mapped over cross-boundary tensions between domain drivers, for example, neither function nor scope were balanced in relation to domain drivers, being counterweighted instead. Decision-making principles and stand-alone references in contract and strategy documents emphasized the coproduction—with agency end users—of research strategy and activity that delivered policy-relevant outcomes (NHRP 2009a). This emphasis was undermined by the structural emphasis on scientific credibility apparent in the design of contractual and participation arrangements, and decision-making roles and responsibilities. Effectively dictating the focus and operating parameters of this organization, these structural elements ensured that the Platform focus remained restricted to producing high-quality research, maintaining research capacity, and managing a collaboration between research providers and a research-funding agency. This strong grounding in the research sector is required of a successful boundary organization. The Platform, however, lacked the balancing grounding in the policy sector required to ensure that collaborative processes and outcomes are as relevant as they are scientifically credible.

As a design tool, this concept is useful because it requires that awareness of domain drivers informs decisions defining the parameters of the boundary organization, with an aim of achieving and maintaining that larger balance between research and policy domains. To make it possible for an organization like the Platform to effect the coproduction of research strategy and outcomes focused on both scientific quality and policy-relevant outcomes, changes to participation, function, and structure would need to be made to ground the Platform in the policy sector, and achieve this balance. Equally, this points to another boundary organization concept requirement—such decisions also need to be internally consistent, or balanced, so that organizational parameters are mutually reinforcing with respect to this larger balance. In the case of the Platform, moves toward this balance would have required increased engagement from the policy domain in every area.

This leads to the second point, concerning the breadth of perspective enabled by the boundary organization concept. The emphasis on balancing domain drivers and interests requires that the relevant collaborative arrangement is assessed in relation to these wider domains, and so in relation to wider social, political, and cultural contexts. When used to assess the Platform, this concept extended the focus of the assessment to include dimensions of the policy domain currently outside this boundary organization's parameters. Requiring that Platform performance was measured in relation to research quality and productivity as assessed in the research domain, research funding agency engagement in this boundary organization largely reinforced the dominance of this research domain driver. This emphasis on domain drivers clarified the extent to which the Platform remained focused on, positioned, and driven from within the research domain, and thus brought the missing range of engagement from the policy domain squarely into frame. Rebalancing the position and focus of this boundary organization would need to be driven from high levels in the policy sector, require a distinct line of accountability to that sector, and would require engagement from a range of end-user agencies at all operational and strategic levels, and at all stages of development.

This also points to the need to ensure equivalent input from research and (end-user) policy domains at the design stage of new boundary organization initiatives in this topic area. Requiring that the same amount of work is done within the policy domain as in the research domain at this design stage would also have the advantage of bringing research and policy representatives together to collaboratively develop participation, functional and structural parameters, in this way beginning the ongoing collaboration to be effected by the boundary organization.

Thirdly, the boundary organization framework is useful because it is capable of analyzing the effects of domain drivers at a range of different levels, because such complex system effects (Song et al. 2005) create self-similar patterns at smaller and larger scales. This affords a perspective that can extend to national or global level (Cash and Moser 2000), while at the same time allowing the contracted focus required for the assessment or design of detailed interactions between organizations, themes, or individuals. The rule requiring that those in the research domain strive for research quality, for example, applies at all levels within this domain, although the detail of how it is defined and understood can vary greatly between the social and physical sciences, between organizations, from one discipline to the next, and between researchers in the same discipline. The fundamental tension between these drivers influences all levels of interaction across boundaries because this is also the case with the rule requiring that those in the policy domain strive for relevance (Sarkki et al. 2014; Van den Hove 2006, 2007; Cash et al. 2003). This scale-free quality made it possible to trace the tensions manifest in the Platform's initial parameters at disciplinary, thematic, and organizational levels, as well as across the boundary between research and policy domains. Facilitating a layered perspective of Platform integration initiatives, this applicability across levels also clarified interdependencies between levels. The Platform was tasked with integrating organizations and disciplines, but a lack of formal mechanisms to induce this task was exacerbated by a loose correspondence between thematic areas and organizational specializations. Similarly, funding contracts between the Platform and member organizations concerning specific research programs did not specify, require, or incentivize integration, and there was no structural provision for integrated Platform decision making in this area (since theme leaders were responsible for research programs). This structural resistance to integration was further compounded at the higher level by a funding agency focus on contractual performance standards concerned with research quality and productivity, measured according to assessment criteria dominated by monodisciplinary journals and review processes, rather than on performance standards concerned with integration. As each level is manifestly driven by concern for research quality, the cumulative effect comes at the expense of the integration required for the production of socially robust knowledge that is socially and politically relevant, as well as scientifically credible. The application of this concept across scales makes it useful when designing or modifying science/policy collaborations. It underlines the need for robust organizational and methodological mechanisms to facilitate integration at all levels, again with a view toward not only increasing integration *per se*, but to ensure that integration efforts remain as balanced as possible. Requiring and incentivizing integrated decision making and methodological agreement within and between themes and organizations, and ensuring that accountability is equally distributed has been linked in related topic domains to stable, stringent forms of interdisciplinarity (Lengwiler 2006). Conversely, when research funding agencies, organizations, and academic communities have more influence over boundary organization decision makers than end users, interdisciplinary integration remains difficult to achieve (Parker and Crona 2012).

Finally, the boundary organization concept is useful when it comes to the effects of disasters on science/policy collaborations in this space. It serves as a useful counterweight to the blame attribution common after high-profile disasters (Birkland 2009). Blame attribution is destructive of resilience at both individual and community levels (Daly et al. 2009), and can prevent evidence-based disaster risk reduction policy by forestalling rigorous investigation of the systemic factors that contributed to the relevant disaster (Birkland 2009). The boundary organization concept is focused on effects, patterns, and trends, rather than individual or organizational performance, and has explanatory force concerning the urgency and time compression that drives blame attribution, and other monocausal disaster explanations (Birkland 2009). Increasing the power of response agencies to influence research and policy decision making, this urgency fueled the intensity and range of operational research collaboration with Platform-coordinated agencies in response to the Canterbury earthquake sequence. Channeling the resources of the wider consortium to generate research activity and outputs that were of high quality and relevant to the operational needs of response and recovery agencies, Platform performance indicated that boundary organizations can be used to integrate national research capacity to provide the accelerated decision making and support required by agencies after major hazard events. The development of the Platform over this period also confirmed that this strong operational performance was not at the expense of research quality, in either Canterbury earthquake sequence-related or overall Platform outputs, because all research quality and productivity standards were met or exceeded over this period. There were indications, however, that the operational integration achieved in response to the earthquake sequence came at the expense of overall integration at thematic, organizational, and sector levels. Although time-pressure is part of the drive for relevance dominant in the policy domain, the time compression created by this disaster appeared to aggravate the drag of research domain drivers on the Platform. This effect is consistent with the preexisting weighting of this organization toward the research domain. Corresponding with a drift away from integration across organizational and thematic boundaries during this period, the aggravation of this preexisting weighting is consistent with the trade-off between postdisaster time compression and the consensus building required to develop integration across disciplinary and sector domain boundaries.

Boundary organizations in this topic area will likely be required to respond to major hazard events. Three points can be made concerning the design of such boundary organizations. First, a longer run up before the advent of a major hazard event would have given the Platform more time for the consensus building required to establish robust, integrated networks between organizations and with agency end users. More established networks would have been likely to increase the Platform's capacity to withstand the negative impact of time compression on integrating activities across domain boundaries, in part through increasing the collective resources brought to bear on postdisaster research coordination. Thus, preexisting boundary organizations, with established integrative networks, are likely to be best placed to coordinate research after major hazard events, and in the process, to minimize negative impacts on both research quality, and integration across disciplinary, organizational, and sector boundaries.

Second, the design of boundary organizations set up to integrate research and policy in the hazard and disaster risk reduction area should anticipate the effects of disasters on organizational structure and operation, and include mechanisms to actively manage these effects after disasters. The Platform's ability to maintain research quality and productivity despite this pressure indicated

that high-level accountability and contractual requirements in the research domain could mitigate the effect of disasters on research quality. This success contrasts, however, with the susceptibility of this organization to the impact of time compression on integrating activity across all domain boundaries, and the associated difficulty producing research strategy and outcomes focused on achieving resilience. Emphasizing the need for a wider range of formalized incentive and accountability measures in general, this contrast draws attention to the lack of equivalent contractual and accountability measures requiring that this organization achieve the integration and focus necessary for policy domain drivers. Including such measures—at all levels—when designing boundary organizations in this area would significantly improve capacity to resist the effects of postdisaster time compression on integration.

Third, it is clear that the incentive and accountability measures that helped mitigate the effect of time compression on the quality of the research produced by the Platform were successful because this organization was strongly grounded in the research domain. It follows that equivalent measures designed to mitigate this effect on the integration and relevance required by policy drivers will be successful to the extent that boundary organizations in this space are equally strongly grounded in the policy domain. Since the time-compressed environment aggravated preexisting imbalances in Platform structure and operation, it is likely that designs that effectively balance the influence of policy and research sectors should increase the resilience of the relevant organization to the risks that arise in the postdisaster environment. Such a balance is only likely to be achieved, however, with significant, high-level policy support and engagement in the establishment and functions of such boundary organizations across the full range of stakeholder agencies at local, regional, and national levels.

This article, like the Platform itself, is largely concerned with integration within the research domain, and between research and policy sectors. There is considerable scope for future research applying this concept in the hazard and disaster area, to policy sector engagement in boundary organizations, to the assessment, design, and implementation of boundary organizations involving multiple stakeholder domains (including business and nongovernmental organizational sectors, and local communities), and when comparing similar boundary organizations from different global regions. Finally, given the extensive application of this concept in the global sustainability and climate change contexts, its application in the disaster risk reduction context also opens the possibility of increased integration between these large issue-driven domains.

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